A climate network perspective on the intertropical convergence zone

Frederik Wolf (1,2), Aiko Voigt (3), Reik V. Donner (1,4)

(1) Potsdam Institute for Climate Impact Research (PIK) - Member of the Leibniz Association, Telegrafenberg Potsdam, Germany
(2) Department of Physics, Humboldt University, Berlin, Germany
(3) Department Troposphere Research, Karlsruhe Institute of Technology, Karlsruhe, Germany
(4) Department of Water, Environment, Construction and Safety, Magdeburg-Stendal University of Applied Sciences, Magdeburg, Germany

EGU 2020

Introduction

Research question? Can data driven approaches contribute to a better understanding of the driving mechanisms of the ITCZ?

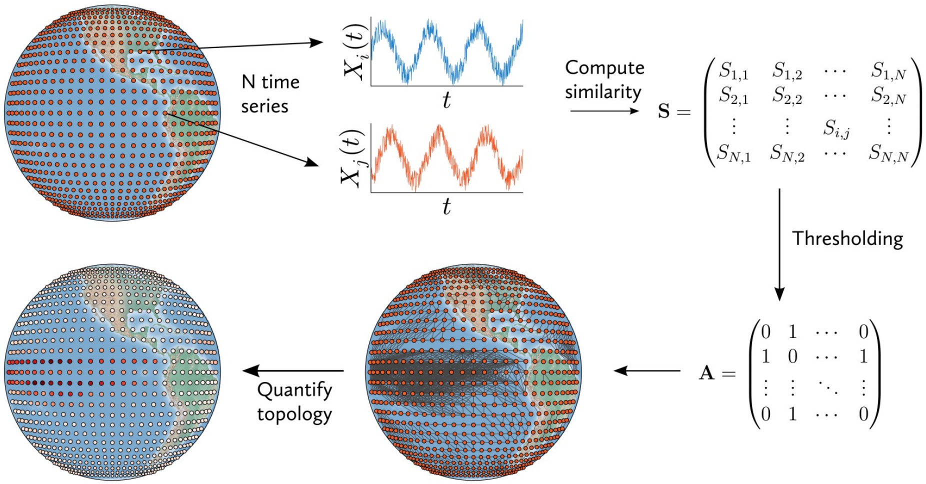
Study setup? Utilize climate networks to analyze outputs from the TRAC-MIP aquaplanet model ensemble

Why? As aquaplanets offer an idealized scenario to solely investigate the formation of the tropical rain belts, this is an excellent condition to study the different correlation structures within the model outputs and isolate different classes of such correlation structures.

Dataset? We utilize the model output from the TRAC-MIP model ensemble (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016MS000748)

Network construction

1. Analyze monthly temperature values covering 30 years (AquaControl runs) or 25 years (Aqua4xCO2 runs) at a spatial resolution of 1°-3° in both latitude and longitude from TRACMIP experiment.



Donner et al., in: Nonlinear and Stochastic Climate Dynamics, Cambridge UP, 2017

2. Compute anomaly time series by subtracting annual mean from each sample of the time series.

3. Compute Pearson correlation coefficient between time series and keep those which represent the 0.005% strongest correlations.

4. Such pairs of nodes are connected by a link in the corresponding network.

Hierarchical clustering of climate models

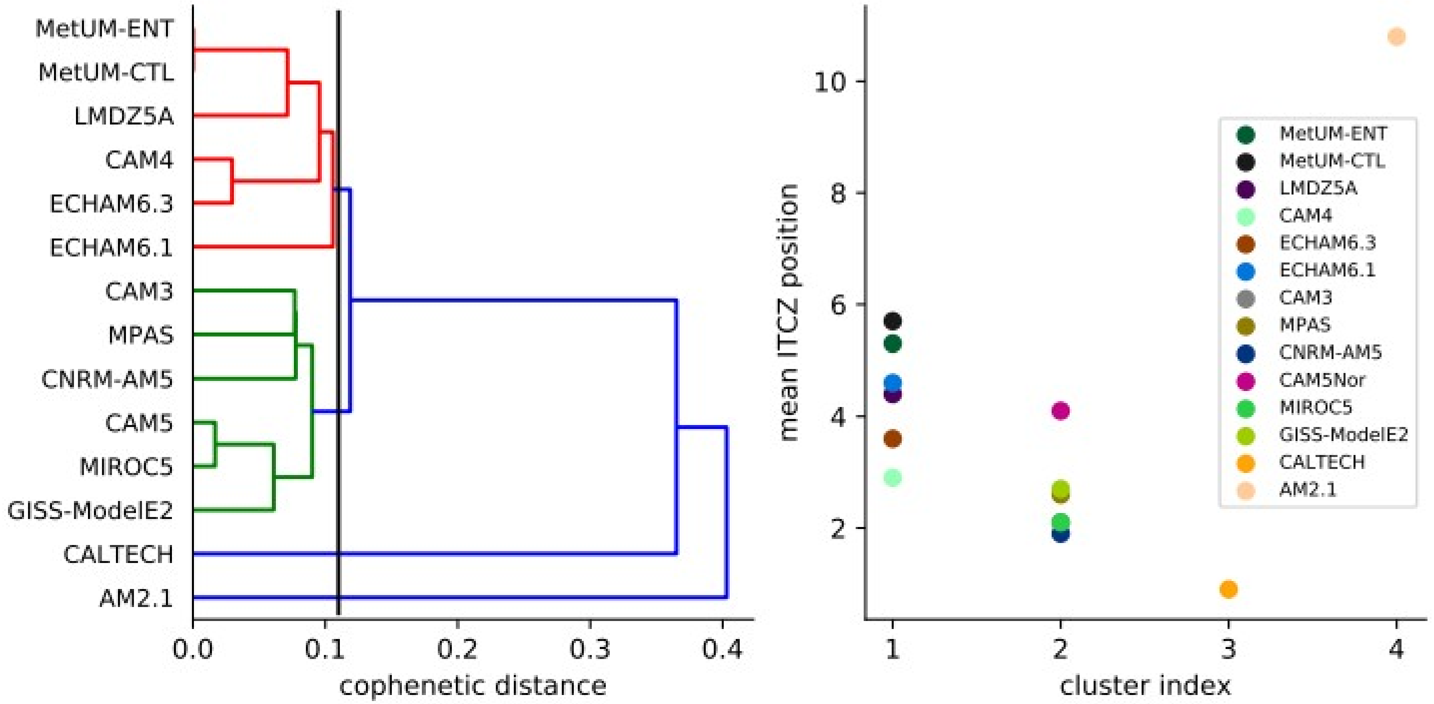
1. Compute zonal mean degree (number of connections per node) and zonal mean link distance (mean physical distance of all connections adjacent to a node) for all networks.

2. Calculate Pearson correlation between all pairs of zonal mean degree and zonal mean link distance.

3. Use the sum of the respective correlation scores as input values for hierarchical clustering using single linkage.

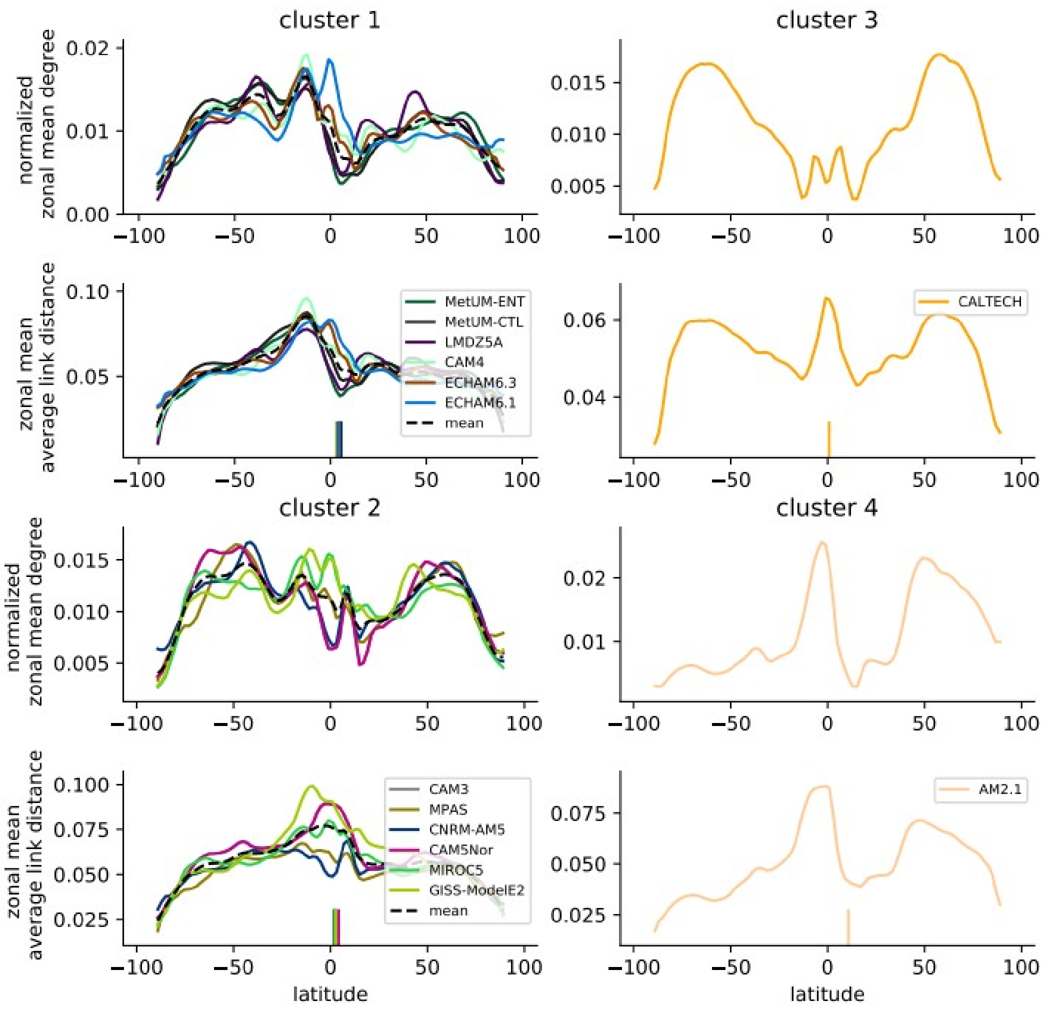
4. Cut resulting dendrogram to obtain clusters of models.

AquaControl – clusters and ITCZ position



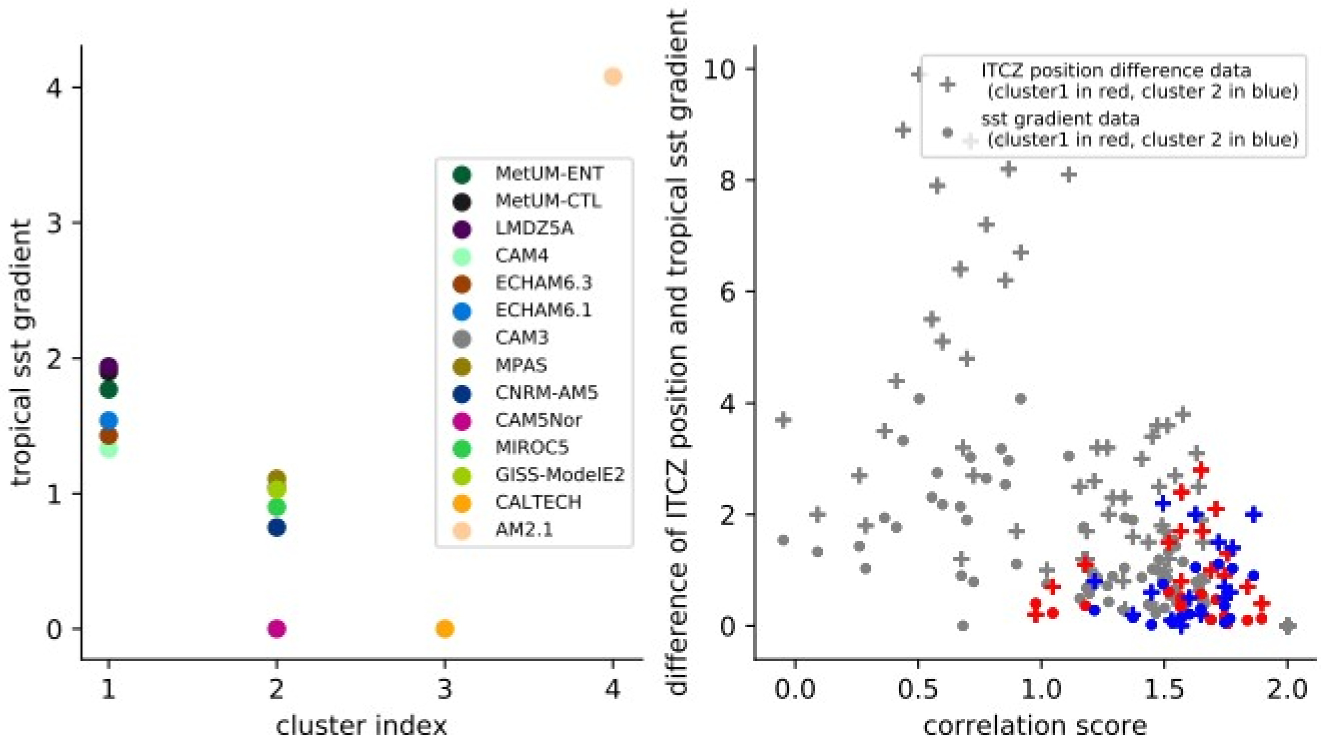
The obtained clusters of models for the AquaControl scenario correlate with the mean ITCZ position of the models in the clusters.

AquaControl – zonal network measures



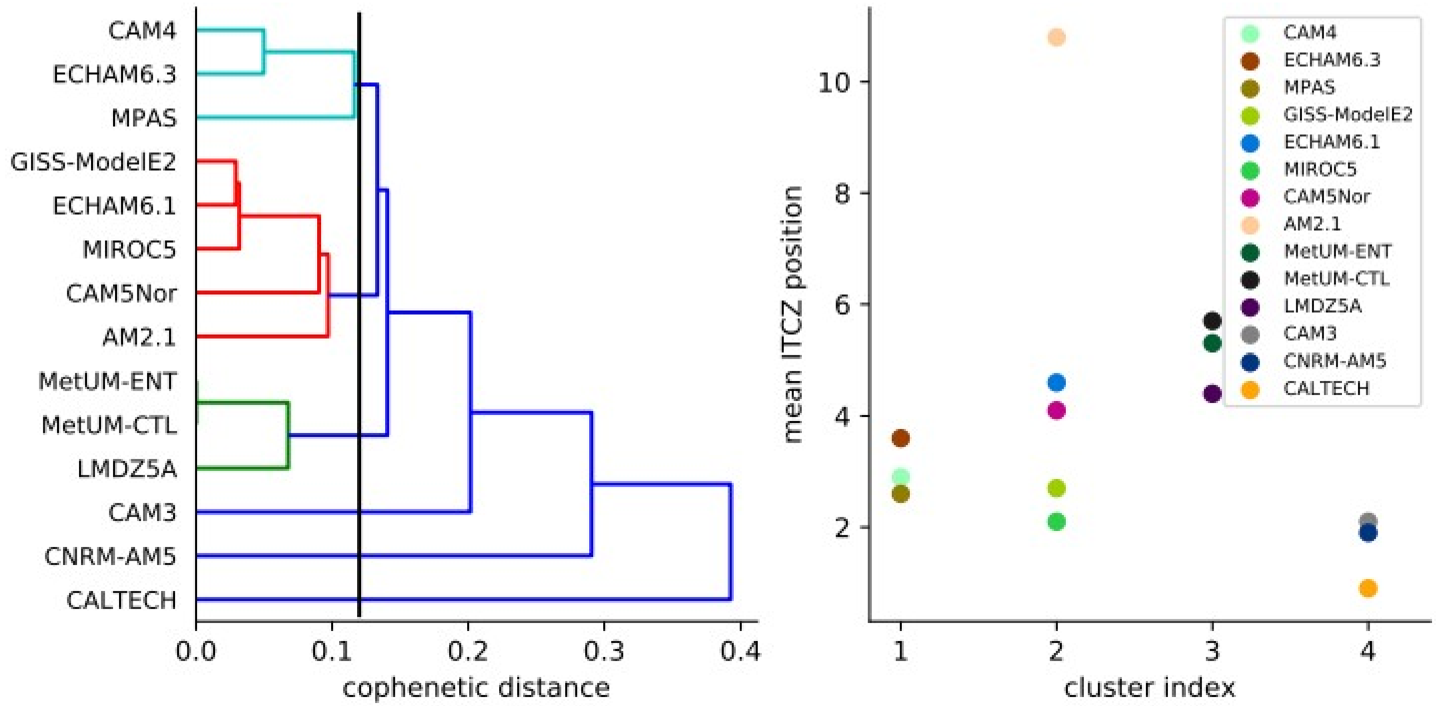
Zonal mean degree and zonal mean average link distance show distinct pattern for each model cluster. Clusters with a more northward shifted mean ITCZ position exhibit more asymmetric structures and elevated values in the region of the southern Hadley cell.

AquaControl – tropical sst gradient/correlation score



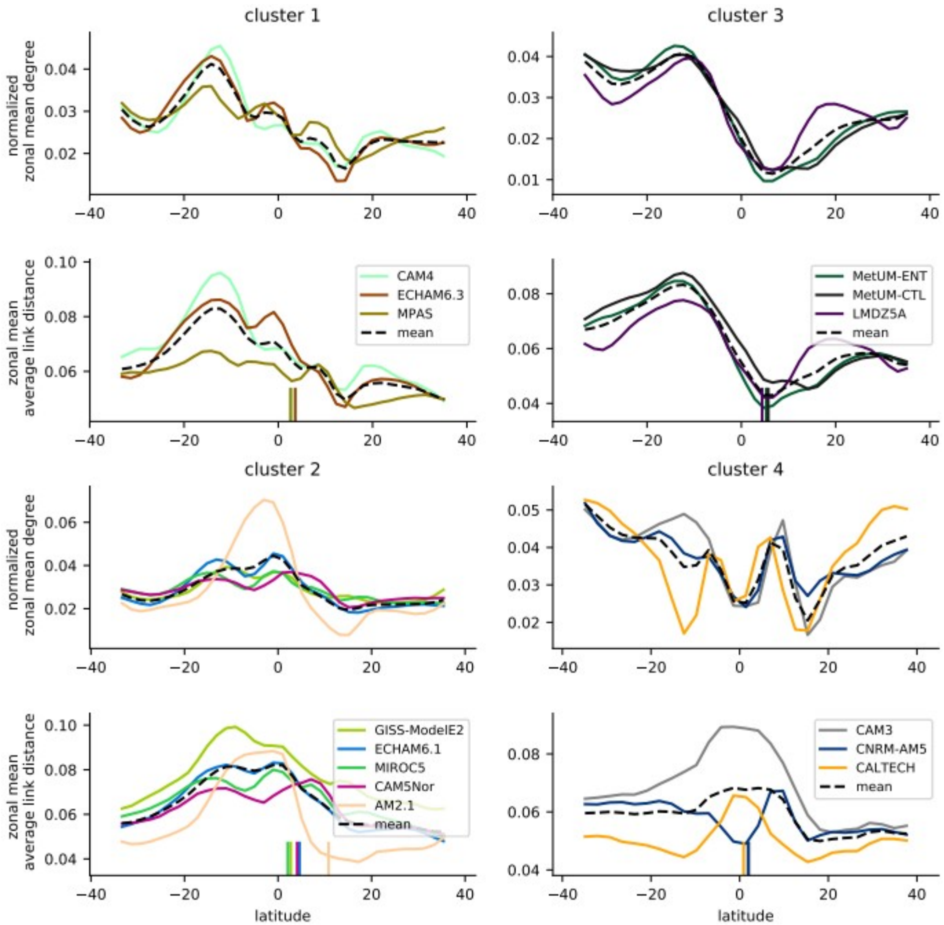
The obtained clusters of models for the AquaControl scenario also correlate with the tropical sst gradient of the models in the clusters.
All model pairs which are grouped in one cluster exhibit above average correlation score and below average difference in mean ITCZ position and tropical sst gradient.

AquaControl – analysis ignoring extratropics-extratropics links



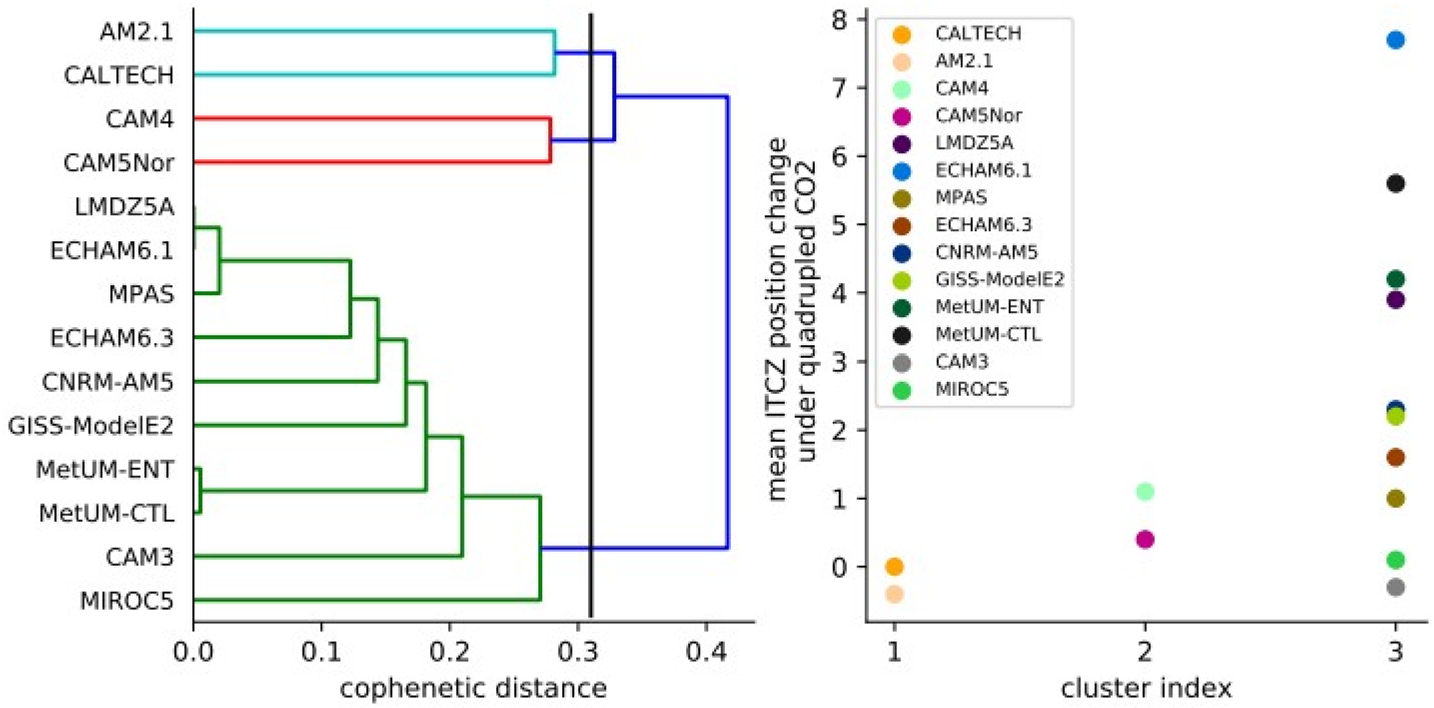
The obtained clusters of models for the AquaControl scenario still correlate with the mean ITCZ position of the models in the clusters. Although we ignore the information hidden in the extratropics-extratropics connections, we can still resolve difference in ITCZ position.

AquaControl – zonal network measures without extratropics-extratropics connections



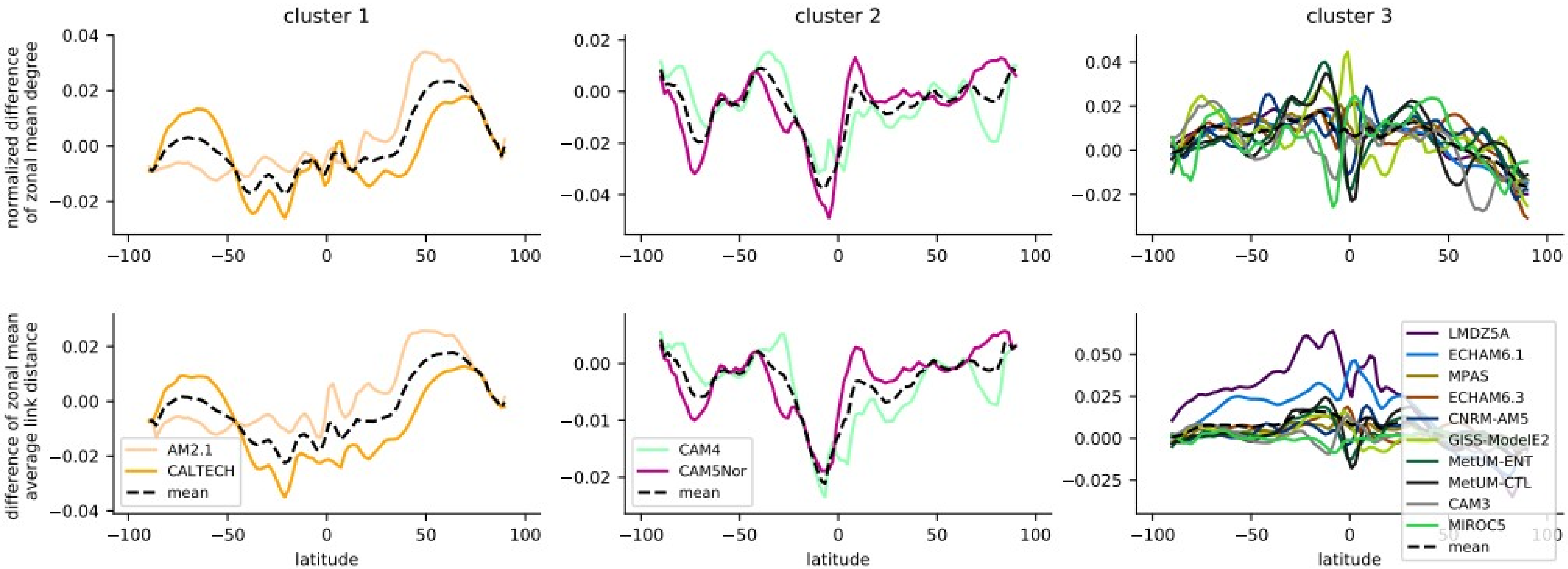
Zonal mean degree and zonal mean average link distance show distinct pattern for each model cluster. Clusters with a more northward shifted mean ITCZ position exhibit more asymmetric structures and elevated values with a clear maximum in the region of the southern Hadley cell.

Aqua4xCO2 – clusters and ITCZ position



The obtained clusters of models for the AquaControl scenario only correlate with the mean ITCZ position change for two 2-models-clusters. The majority of the models do not exhibit interpretable group structure by the means of climate network structure change under quadrupled CO_2 conditions.

Aqua4xCO2 – zonal network measure differences



Shown are the network measure differences between the AquaControl and Aqua4xCO2 related networks. We we do not find a clear tendency among the clusters. We still note a general trend of decreasing network measures on the northern hemisphere and a corresponding trend of increasing northward shift of the mean ITCZ position for cluster 3 models.

Summary and outlook

1. Functional climate networks can unveil distinct structures which are connected to the mean position of the inter-tropical convergence zone.

2. Asymmetric network measure distributions and elevated values in the region of the southern Hadley cell coincide with strongly northward shifted ITCZ positions.

3. Extratropics-extratropics (tele)connections might be of minor importance as we are able to find meaningful clusters of climate models without considering them.

4. Tropics-Extratropics (tele)connections might be of major importance as an exclusion of them prevents us to identify meaningful clusters.

Still to do: Climatic interpretation of the found features with respect to the different model setups.

Work to be submitted to ESD